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THE WATER SUPPLY OF THE NIAGARA FRONTIER[1]

By R. C. Snowden[2]

From the importance which water bears to the carrying on of most animal and vegetable existences, it is safe to say that no other single article of use is so valuable or so little considered in our daily economy as this material.

The necessity for safe and appropriate waters have appealed to people of all ages and particularly to such as have reached the higher stages of civilization. The Romans have left many examples of their efforts conscientiously to safeguard the health of their communities, in the aqueducts scattered over southern and western Europe. There are even traces of hydraulic canals used by the Babylonians, their history buried in antiquity, which were presumably employed for irrigation purposes, but whose use no doubt was industrial and sanitary as well. Who can say?

The pioneer going into new territory finds his wants supplied by such things as have taken care of the human or brute life preceding his advent, and his water requirements are satisfied if he can find a stream or spring furnishing a sufficient quantity and of such kind as not to offend the senses. His practice is reasonably safe in most temperate and frigid climates and localities. After people have congregated in communities the question of water supply becomes a problem and the complexities of modern industrial and sanitary conditions have at last forced us into taking definite and positive steps to safeguard our processes and our people from natural and artificial impurities which are to be found in practically all surface and underground waters, and upon which supplies we are generally forced to depend.

With the exception of small amounts of carbon dioxide, ammonia and dust, rain water no doubt affords a supply of the best and softest water for most industrial uses, but the amount is limited and unreliable, so it is necessary for us to turn to the rivers and lakes which have the ability to furnish us with an abundant supply, but which unfortunately have become so loaded with soluble and insoluble matters as to disturb or destroy their usefulness by their passage over and through the soil and rocks of the earth's surface. Operators of steam boilers without question feel the effect of these dissolved materials in the form of "scale" more than anyone else. Dyers and bleachers are much hindered in their work by the presence of lime and magnesium salts and iron compounds. Tanners require water that is relatively free from calcium and magnesium carbonate, and the manufacturer of artificial ice must use water which is as free from pathogenic bacteria as possible, the presence of an ordinary amount of mineral matter being of small consequence.

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Fortunately, industrial needs may be defined as requiring water that shall contain a minimum of the compounds causing what is commonly termed "hardness." By this we mean the salts of calcium and magnesium in solution which break up the compounds sodium or potassium stearate, etc. soap, with the formation of the corresponding calcium or magnesium compounds. These latter are relatively insoluble in water and have no detergent value and must be practically all precipitated before the soap can accomplish the formation of lather and the assumption of its value as an agent for washing. The so-called "hardness" of water is commonly classified as "permanent" and "temporary," the former representing those salts that remain in solution after prolonged boiling of the affected water and the latter those salts which are precipitated by heat as a gray or brown deposit. Practically every tea kettle in the neighborhood of the Niagara River is seriously affected by this disease. I may say with respect to the hardness of the water that it will run around 14 degrees, about 14 grains of calcium salts to the gallon.

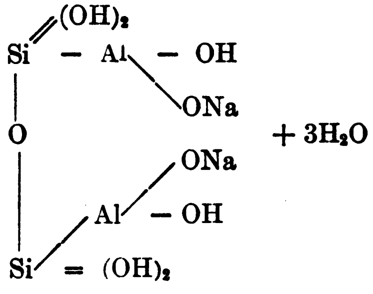
As an example of conditions against which we have to contend in these parts, I should like to mention the analysis of Niagara River water. There is no reason to doubt that very nearly the same condition pertains in all parts of the stream over the same cross section. Our "hardness" here is due to the fact that the river flows over a layer of dolomitic lime stone (i.e. calcium-magnesium carbonate with inclusions of calcium sulphate) on its way from Lake Erie. These figures indicate that the impurities which are to be considered from an economic standpoint are the calcium carbonate, magnesium carbonate and calcium sulphate, together with silica representing chiefly suspended matter in the form of silt.

These compounds are readily precipitated from solution by lime water or soda treatment according to well known methods and by means of many different forms of suitable apparatus. As a matter of fact the hardness of the river water is of such small amount as to affect only moderately the proper operation of steam boilers, although in some of our up-to-date plants running under fine control the removal of offending material is assuming notable proportion, and large steam users are inclined to conserve coal and labour by using the softest possible water.

The most recent systems for securing soft water are those employing the so-called zeolites, either artificial or natural. These materials are hydrated silicates of aluminum and sodium having an empirical formula as follows:

$$2SiO_2 \cdot Al_2O_3 \cdot Na_2O \cdot 6H_2O$$

and a hypothetical structural formula:



These substances have the property of giving up their sodium in favour of calcium and magnesium when hard waters are filtered through the finely crushed material held in suitable pressure filter tanks, until finally all of the sodium has been replaced and the "calcium magnesium zeolite" is left. The bed is renewed by soaking the zeolite bed with a weak common salt solution when an opposite reaction takes place and the "sodium zeolite" which is reformed is then ready to perform its work as before. Recent figures indicate that a plant suitable for softening 200,000 gallons of Niagara River water to zero hardness would cost in the neighbourhood of $14,000.00 ready to operate. The cost for salt at $10.00 per ton would be about $10.00 per day, and attendance may almost be ignored. If we allow

$18.00 per day for depreciation and all, a cost of 8–10 cents per 1000 gallons is obtained which seems rather high, since usually our local waters may be treated with soda ash at a cost of 2–4 cents per 1000 gallons.

The system I have indicated will reduce "hardness" to nothing; it makes clothes whiter and better.

For the manufacture of fine chemicals it is often necessary to provide a supply of water that shall be free from any foreign material, and in this case there seems to be only one remedy, the use of water which has been vaporized and subsequently condensed, distilled water. For this purpose, several different types are on the market, most of them efficient and reliable, varying from single effect evaporators to sextuple effect, with the single effect machines used for small quantities of water up to 200 to 300 gallons per hour. They are usually operated by steam from the boiler plant, and with coal at $4.00 per ton, the distilled water will cost in the neighbourhood of $5.00 per 1000 gal., attendance and maintenance being slight. An increase in the cost of coal will increase the estimate for distilling water.

PUBLIC WATER SUPPLY

G. C. Whipple has given the qualities of public water supply which most affect the ordinary consumer as:

1. Its sanitary quality; that is, its liability of infection with disease germs or substances deleterious to health.
2. Its attractiveness or lack of attractiveness as a drinking water.
3. Its hardness, as far as this relates to the use of soap in the household.
4. Its temperature, as far as this relates to drinking.

Nature's way of treating water is either to send it as rain or to purify it by filtration, passing it through a portion of the earth's crust or over the sand and gravel of river courses.

Sand filters, as engineering structures, were built as early as 1874 at Poughkeepsie and at Hudson N. Y. under the direction of Mr. James Kirkwood.

Many forms of filters are in use, no two being alike in relative proportions or in method of use, but in nearly every case they may be divided into two classes:

1. Slow sand filters, which consist of large beds four to ten feet thick of graduated sand, with under drains.

2. Rapid sand or mechanical filters, covering an area of only a few thousand square feet for an output of several million gallons per day, contain 2 to 6 feet of graduated sand and are operated most intensively.

The filters of the first class depend for their efficacy upon the marine growth, which forms a gelatinous coating to a depth of some inches down from the top of the sand. This coating serves to entrain the bacteria in the raw water. If well operated these filters are satisfactory and produce better results on waters relatively free from color or clay silt. At intervals the fouled layer of sand needs to be scraped off and replaced by fresh sand. Some treatment with coagulant may be used if desired. This usually consists of alum, iron sulphate or lime.

The capacity of a good slow sand filter should be in the region of 3,000,000 gallons per 24 hours per acre. The cost of operation will run from $6.00 to $10.00 per million gallons.

Filters of the second class in many ways resemble the slow sand filters, but have a much smaller area for the same output, require more attention as to quantity and control of coagulant and must be cleaned more frequently. The cleaning is accomplished by stirring up the bed with filtered water and air, mechanically done and with a minimum of labour. The cost of water filtered by this method is the same as in the case of the slow sand filters. Rapid sand filters are generally preferred to the slow sand filters on account of the lower first cost, which is about one-half of that for slow sand beds.

In spite of the fact that the natural or artificial coagulants do remove all of the suspended matter and most of the bacteria present in the raw water, it has been found essential at most filter plants to install some means for disinfecting the water either before or after filtration. This has been accomplished to date almost entirely by the use of liquid chlorine, bleaching powder (calcium hypochlorite) or chloramine (NH_2Cl formed by reaction of ammonia in solution with chlorine gas). At a few points, notably in Europe, ozone and ultra violet light are being used. According to C. G. Hyde in a paper presented to the League of California Municipalities in October 1911, there is selective action in the case of hypochlorites tending to destroy pathogenic bacteria in preference to harmless ones. I quote as follows:

> All vegetable bacteria cells succumb readily to the action of this oxidizing agent. The spore forms however, encased as they are with heavy protecting

walls which frequently render them capable of successfully withstanding continued boiling, are not destroyed by such quantities of hypochlorite as it would seem rational to apply to water supplies. Fortunately, the bacteria of the intestinal tract, including the normal inhabitants thereof, such as B. coli, and such pathogenic forms as the bacteria of typhoid fever, cholera, etc., are not spore formers and are, therefore, not able to resist the action of the hypochlorite when applied in sufficient amounts. In so far as the non-spore formers are readily destroyed, it may be said that the germicidal action of hypochlorites is selective and especially destructive to the dangerous species.

Chlorine has been found to be just as efficacious and, in the opinion of many, easier and more reliable in application. The use of chloramine was found to be desirable at Ottawa in 1915.

Unfortunately filtration of water for community use does not naturally change the relative hardness of the filtered water from that of the raw water, so a filtered hard water still requires treatment if dissolved compounds interfere with its industrial value.

In order to bring some of the practical aspects of this priceless civic adjunct to your attention it would seem desirable to present at this point some of the local information which is available.

Previous to January 1912, the City of Niagara Falls, N. Y., had been furnished with water pumped from the Niagara River, at an inshore point near the Niagara Falls Power Company or about one half mile above the Falls. The water of the city was notorious for its poor condition, as it was both muddy and unquestionably loaded with sewage from the upriver communities, Buffalo and Tonawanda.

As might be expected, dilution and natural causes have reduced the bacterial content of the water at the outlet of Lake Erie to 200–400 bacteria per cubic centimeter, while the south shore of the river is badly polluted. The west river, which is important to the Canadian side, has a bacterial content comparable to that of Lake Erie. Were it not for the mechanical impurities of the river water engendered during storms, etc., the water could unquestionably be made suitable for consumption on the Canadian side by simply disinfection, by liquid chlorine, as is done at Buffalo. This is hardly true. It is reasonable to judge that conditions on the Canadian side will have to be met as they have been on the American side or at Toronto and Montreal, in the provision of suitable settling and filtering devices.

In order to emphasize what has taken place at Niagara Falls, as a direct result of the filtering of the water supply of the City by the municipal plant, and that of the Western New York Water Company, we may say that in December, 1911 (before filtration commenced) there were 42 typhoid cases reported, in January (during which month the plants were started operating) there were 28 cases reported, in February there were 12 cases, and since that time the number has varied from 0 to 5 with an average of 1 to 2. For a period of several years there have been many months which have no deaths recorded against them except on two occasions when definitely polluted dug wells started local epidemics.

From 25,000 to 30,000 people are being served by the municipal plant, together with several large industrial operations. The cost for the year 1919 has been less than $8.00 per million gallons, with a per capita daily consumption of about 200 gallons, since the factories use about half the water. This makes the per capita cost about 0.3 cent per person served per day.

The bacterial contamination on the south shore is much worse than on this side; from 140,000 to 20,000 per c.c. on the south shore to around 200 to 400 per c.c. on this side.

In conclusion, let me impress upon the members of this Association who, as engineers and patriotic citizens of this growing country, have the opportunity to lead civic thought along such channels as may be for the best good of the community, the unquestionable necessity of looking these problems straight in the face. A responsibility rests upon you, and at no time should false economy be permitted to jeopardize in the slightest the health and welfare of those whom you have the power to protect. What aggregation of people is willing to return to the earlier conditions, after they have experienced the benefit of a clean water supply? Who can consider the cost when it is so small?